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Daily Antecedents and Consequences of Nightly Sleep

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Summary

Sleep can serve as both cause and consequence of individuals' everyday experiences. We built on prior studies of the correlates of sleep, which have relied primarily on cross-sectional data, to examine the antecedents and consequences of sleep using a daily diary design. Specifically, we assessed the temporal sequence between nightly sleep and daily psychosocial stressors. Parents employed in a U.S. information technology company (N=102) completed 8 consecutive daily diaries at both baseline and one year later. In telephone interviews each evening, participants reported on the previous night's sleep hours, sleep quality, and sleep latency. They also reported daily work-to-family conflict and time inadequacy (i.e., perceptions of not having enough time) for their child and for themselves to engage in exercise. Multilevel models simultaneously testing lagged and non-lagged effects revealed that sleep hours and sleep quality were associated with next-day consequences of work-to-family conflict and time inadequacy, whereas psychosocial stressors as antecedents did not predict sleep hours or quality that night. For sleep latency, the opposite temporal order emerged: on days with more work-to-family conflict or time inadequacy for child and self than usual, participants reported longer sleep latencies than usual. An exception to this otherwise consistent pattern was that time inadequacy for child also preceded shorter sleep hours and poorer sleep quality that night. The results highlight the utility of a daily diary design for capturing the temporal sequences linking sleep and psychosocial stressors.

Keywords

Daily diary; sleep hours; sleep latency; sleep quality; work-family conflict; time inadequacy

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Sleep is central in everyday life and can be both a predictor and outcome of daily experiences. For example, psychosocial stressors, such as interpersonal tensions and work demands, influence sleep (Barnes, 2012, Berkman et al., 2010), and sleep also is linked to perceptions of stressors (McEwen, 2006, Sonnentag et al., 2008). Most of this research has used cross-sectional or retrospective designs, approaches that are unable to capture the temporal sequencing between nightly sleep and daily experiences. Using longitudinal daily diary data involving consecutive nightly telephone interviews with mid-life, employed parents, this study examined the daily antecedents and consequences of nightly sleep, specifically, sleep hours, quality, and latency.

Work-to-family conflict and time inadequacy are psychosocial stressors that may affect or be affected by sleep patterns. Work-to-family conflict occurs when demands from work interfere with family and personal life (Netemeyer et al., 1996, Voydanoff, 2005) and is negatively associated with employees' sleep (Berkman et al., 2015, Buxton et al., 2016, Crain et al., 2014). Time inadequacy refers to perceptions of not having enough time for one's family and personal life (Hill et al., 2013, Lee et al., 2015). Specifically, inadequate time to be with one's child is a common stressor, experienced by many employed parents who are juggling work and family roles (Milkie et al., 2004). Time inadequacy for self is a significant barrier to self-care behaviors, including being more physically active and less sedentary (American Psychological Association, 2012); recent evidence shows that time inadequacy for exercising impairs daily well-being (Lee et al., under review). Despite its potential implications, we know little about the associations between time inadequacy and sleep. This study focused on three key psychosocial stressors – daily work-to-family conflict, daily time inadequacy for child, and daily time inadequacy to engage in exercise – all of which may be negatively linked with employed parents' nightly sleep.

Some prior research using retrospective survey designs suggests bidirectional links between sleep and stressors, with important implications for future health outcomes (Benham, 2010). In this study we aimed to advance understanding of the temporal directionality between sleep and psychosocial stressors, relationships that may vary across sleep variables. Sleep hours and sleep quality reflect *replenishment of resources* (e.g., energy level, cognitive recovery) and thus may relate to the next day experiences, including perceptions of daily stressors. Sleep latency refers to the time it takes to fall asleep and may relate to the current day's *worries and concerns.* Previous studies suggest that sleep hours and sleep quality may lead to next day stressors, whereas daily stressors may lead to sleep latency that night. For example, lab-based experimental studies report that previous night's sleep deprivation predicts poorer executive functioning the next day (Nilsson et al., 2005, Sonnentag et al., 2008). Research using ambulatory polysomnography shows that more bedtime worries and concerns predict longer time to non-REM Stage 3 from sleep onset (Akerstedt et al., 2007). These studies, however, did not rule out the opposite order, leaving a gap in understanding the temporal directionality between psychosocial stressors and sleep. Considering the potential for mutually reinforcing effects of sleep and daily stressors, it is necessary to apply a rigorous analytic approach that can test whether and how temporal directionality varies across sleep variables.

Our study design involves eight days of assessment and enables testing each direction of effect, controlling for the other direction. Recent work separately testing temporal directions suggests that nights of longer sleep hours and better sleep quality predicted perceiving fewer stressors or less negative affect the next day, however, stressors or affect did not predict same-night sleep hours or quality (Bouwmans et al., 2016, Sin et al., 2015). Advancing that work, the current study simultaneously tested the two competing directions (i.e., sleep → daily stressor, and daily stressor → sleep) in single, lag-based analytic models (Starr and Davila, 2012). For example, we tested whether sleep hours and sleep quality preceded perceived stressor experiences the next day, after controlling for the effects of daily stressors predicting same-night sleep hours and sleep quality. Moreover, our daily diary data allow for examination of ecologically valid, naturally occurring specific types of psychosocial stressors important for employed parents (i.e., daily work-to-family conflict, daily time inadequacy for child and for self to engage in exercise) and their associations with nightly sleep (Bolger et al., 2003). Based on these previous findings, it is plausible to expect (Figure 1) that shorter sleep hours and lower sleep quality (both linked to less replenishment) would precede more work-to-family conflict and/or time inadequacy the next day, but that more work-to-family conflict and/or time inadequacy on a given day would precede longer sleep latency that night (signaling worry). However, given that rigorous tests of temporal directionality are limited, we systematically explore bidirectional links.

Method

Participants

Data came from the Work, Family, and Health Study (Bray et al., 2013, King et al., 2013). Researchers partnered with the information technology (IT) division of a U.S. Fortune 500 company, and IT employees working in the metropolitan areas with the two largest workforces were invited to participate in the study. Field interviewers administered face-to-face, Computer-Assisted Personal Interviews (CAPI) to employees at the workplace between September 2009 and September 2010 to collect data on demographic and work characteristics.

Among 823 employees who completed a baseline CAPI workplace interview, 209 parents who had children aged 9–17 were eligible and invited to participate in a diary study (the child closest to age 13 was the target child). Of these, 131 participated at baseline (62.7% response rate), and 102 completed a follow-up assessment 12 months later (77.9% retention rate). The attriters (n=29) and non-attriters (n=102) did not differ on demographics, including age, gender, marital status, and household income. Analyses focused on the 102 employed parents who provided longitudinal daily diary data.

At baseline, participants' mean age was 45.19 (SD = 5.87); 54% were men; 79% had completed four years of college or more and 20% had some college (1–3 years) or technical school; and mean annual household income was in the $120,000–$129,999 range. Participants worked 511.80 (SD = 71.92) minutes or 8.53 hours per day during the diary week. Most (83%) worked regular daytime schedule; the rest worked variable schedules (that changed day-to-day, but not night or evening shift, *per se*). Mean number of children was 2.11 (SD = 1.17), and children averaged 13.32 years of age (SD = 2.26).

Procedure

The diary data collection took place in the month following the workplace CAPI interview. Participants were telephoned on eight consecutive evenings and asked about their daily experiences for the past 24-hour period or from 7 p.m. on the prior day for the first call. Each call lasted about 20 minutes, and participants received $150 at baseline and $250 at the 12-month follow-up for their participation. After the baseline interviews, a workplace intervention was implemented, which aimed to decrease employees' work-family conflict through increasing supervisor support and schedule control (Kelly et al., 2014, Kossek et al., 2014). Testing the intervention's effects was not the focus of the current study (and no significant effects emerged for the sleep measures used here); however, we controlled for intervention participation in the analyses. This study was approved by appropriate Institutional Review Boards and conducted in accordance with the Declaration of Helsinki.

Daily Diary Measures

Sleep hours—Each evening, respondents were asked "How many hours did you sleep last night?" with allowed responses in hours and minutes. We also conducted supplementary tests of sleep duration by calculating time in bed as the number of minutes between participants reports of time going to bed ("What time did you go to bed last night?") and waking up ("What time did you wake up this morning?).

Sleep quality—We used one item adapted from the Pittsburg Sleep Quality Index (PSQI; Buysse et al., 1989): "How would you rate (your/last night's) sleep quality overall?" Responses ranged from 1 (*very badly*) to 4 (*very well*), with higher scores indicating higher quality.

Sleep latency—Sleep latency was measured by one item from the PSQI (Buysse et al., 1989), asking "How long did it take you to fall asleep?" Responses coded in minutes.

Work-to-family conflict—We used the mean of a five item scale adapted from Netemeyer et al. (1996), e.g., "Since this time yesterday, how much did the demands of your work interfere with your family or personal life?" Responses ranged from 1 (*not at all*) to 4 (*a lot*), with higher scores reflecting greater conflict. These questions were only asked if participants worked in the previous 24 hours. Reliability was calculated at both the between- and within-person (across days) levels (Cranford et al., 2006), and both were adequate (between-person α = .85; within-person α = .76).

Time inadequacy—Participants rated two items from the Family Resource Scale-Revised (Van Horn et al., 2001) to report on perceived time inadequacy for child and self, e.g., "Since this time yesterday did you feel that you did not have enough time: to be with your (target) child? to exercise?" Responses ranged from 1 (*strongly disagree*) to 5 (*strongly agree*), with higher scores reflecting higher time inadequacy.

Covariates—Sociodemographic, work, and family characteristics may relate to work-to-family conflict and time inadequacy as well as sleep (Burgard, 2011, Maume et al., 2010), so we controlled for age (in years), gender (0=*men*, 1=*women*), marital/partner status

(0=*unmarried*, 1=*married or living with a partner*), race (0=*non-white*, 1=*white*), educational level (0 = *less than college graduate,* 1 = *college graduate or more*), number of children, and target child's age (in years) and gender (0 = *boy*, 1 = *girl*). An organizational merger in the IT firm was announced when about half of employees had received the intervention and the other half had not so we controlled for potential merger effects (0=*intervention pre-merger*, 1=*intervention post-merger*). Moreover, parents' work schedule control (*M* = 3.58, *SD* = 0.74), work hours in minutes (*M* = 511.82, *SD* = 71.74), and the proportion of their workdays across diary days (*M* = 0.75, *SD* = 0.09) were included to take into account their work-related resources and time availability (Basner et al., 2007). Lastly, we considered potential differences as a function of intervention condition (0=*control*, 1=*intervention*), time of measurement (0=*baseline*, 1=*12 months*), day-of-week (0=*Sun* to 6=*Sat*), and the previous night's sleep responses in the models. All continuous variables were centered at sample means.

Data Analysis—We used multilevel modeling in SAS 9.4 to take into account the clustered data structure: 1,632 daily observations across the two waves of measurement (i.e., baseline and 12 months) clustered within 102 persons (Bryk and Raudenbush, 1992). Three-level models with a specific variance classification (i.e., a first-order autoregressive variance structure) accounted for the fact that consecutive sleep observations within each wave might be more highly correlated than non-consecutive observations. Two waves of data provided more statistical power to simultaneously test two temporal sequences with both lagged and unlagged variables because the first day's reports at each wave are missing in a lagged design. To test our hypotheses about the temporal sequence between nightly sleep and daily stressors, variances for key measures were decomposed to Within-Person (WP; level-1) and Between-Person (BP; level-2) levels. WP variables were centered at the person mean, such that positive values indicate scores higher than the person's own cross-time average. BP variables were centered at the sample mean, such that positive values indicate higher scores than others in the sample. We separately modeled sleep hours, sleep quality, and sleep latency in each multilevel model, including work-to-family conflict, time inadequacy for child, or time inadequacy for self in the equation (9 sets of analyses). For example, the level-1 model for nightly sleep hours in relation to daily work-to-family conflict (without covariates) was specified as:

$$\begin{aligned} \textit{Last Night's Sleep Hours}_{\mathrm{d-\ 1i}} = \beta_{0\mathrm{i}} + \beta_{1\mathrm{i}}\,(\mathrm{Prior\ Night's\ Sleep\ Hours}_{\mathrm{d-\ 2i}}) \\ + \beta_{2\mathrm{i}}\,(\mathrm{Today's\ Work\text{-}\ to\text{-}\ Family\ Conflict}_{\mathrm{di}}) \\ + \beta_{3\mathrm{i}}\,(\mathrm{Prior\ Day's\ Work\text{-}\ to\text{-}\ Family\ Conflict}_{\mathrm{d-\ 1i}}) + e_{\mathrm{di}} \end{aligned}$$

Because sleep hours reported on a given day were about last night's sleep, the day of sleep hours was *d-1* in relation to other daily variables. Here, β_{0i} represents person *i*'s intercept, which is the function of the sample mean (γ_{00}, intercept), the effect of the BP level work-to-family conflict (γ_{01}), and random deviations of person *i*'s mean from the sample mean (μ_{0i}). β_{1i} represents whether the prior night's (i.e., the night before last night's) sleep hours on day *d-2* (i.e., a one-day lag) predict sleep hours on day *d-1* (see also Figure 1). β_{2i} indicates whether changes in sleep hours on day *d-1* (residualized gains after controlling for β_{1i}) are associated with work-to-family conflict on day *d* (after controlling for β_{3i}). β_{3i} indicates whether work-to-family conflict on day *d-1* (i.e., a one-day lag) is associated with changes in sleep hours from the night before to that night (i.e., on *d-1*, after controlling for β_{2i} as well as β_{1i}). Residual error, e_{di}, denotes random variation of person *i* on the d^{th} day from person *i*'s mean. Simultaneously testing both β_{2i} and β_{3i} in a single model allows us to determine whether sleep hours – and also sleep quality – precede the next day stressors (β_{2i}) or whether daily stressors precede same-night sleep hours or sleep quality (β_{3i}). Similarly, nightly sleep latency was modeled in relation to daily work-to-family conflict, time inadequacy for child or for self to exercise. The simplified model (without covariates) for nightly sleep latency in relation to daily time inadequacy was specified as:

$$\begin{gathered} \textit{Last Night's Sleep Latency}_{\text{d- 1i}} = \beta_{0\text{i}} + \beta_{1\text{i}} \left(\text{Prior Night's Sleep Latency}_{\text{d- 2i}}\right) \\ + \beta_{2\text{i}} \left(\text{Today's Time Inadequacy}_{\text{di}}\right) \\ + \beta_{3i} \left(\text{Prior Day's Time Inadequacy}_{\text{d- 1i}}\right) + e_{\text{di}} \end{gathered}$$

As shown in Figure 1,. β_{2i} indicates whether sleep latency precedes time inadequacy the next day, after controlling for β_{3i} indicating time inadequacy (i.e., a one-day lag) precedes same-night sleep latency, and *vice versa*.

Results

Table 1 presents baseline descriptive statistics and correlations of all variables. The WP level correlations between the sleep measures indicated that sleep hours were positively associated with sleep quality and negatively associated with sleep latency. Sleep quality was also negatively associated with sleep latency. The BP and WP level correlations ranged from -0.27 to 0.44, meaning that each of the sleep measures were distinct constructs. The Intra-Class Correlations (ICCs) of daily work-to-family conflict, time inadequacy for child and self, and sleep variables suggested that high proportions of the variability in these variables were due to day-to-day fluctuations rather than between-person differences, which meant that it was appropriate to test temporal directionality between them.

Table 2 shows the effects of covariates on sleep hours, sleep quality and sleep latency. Beginning with *sleep hours*, participants slept 6.4 hours per day on average, after adjusting for sociodemographic, work, and family characteristics. Married participants reported longer sleep hours than unmarried counterparts but there were no differences as a function of other sociodemographic and work characteristics. Participants tended to increase (at a trend level) sleep hours across 12 months, and the previous night's sleep hours were negatively linked to the current night's sleep hours. With regard to *sleep quality*, participants reported "good" sleep on average (intercept=2.89, where 3 means good/well). There were no differences by sociodemographic and work characteristics, but participants reported better sleep quality as the week progressed (from Sunday through Saturday nights) and on nights following those with lower sleep quality. In terms of *sleep latency*, participants reported taking an average of 29 minutes to fall asleep per night. Married participants reported shorter sleep latencies than unmarried participants, and the previous night's sleep latency was negatively linked to the current night's sleep latency.

After adjusting for all the covariates, in Model 2 (Table 3), sleep hours and sleep quality the previous night were associated with current day work-to-family conflict: On days following shorter sleep hours or lower sleep quality than usual, participants reported higher work-to-family conflict than usual. Sleep latency, however, was linked to same day work-to-family conflict: It took longer to fall asleep on nights when participants had experienced greater work-to-family conflict over the course of the day. These effects were found after controlling for the opposite temporal sequence, which was not significant.

Daily time inadequacy variables were added in Model 3 and Model 4 (Table 4). As with work-to-family conflict, the previous night's sleep hours and sleep quality predicted current day time inadequacy: On days following shorter sleep hours or lower sleep quality than usual, participants reported higher time inadequacy for their child and for themselves to exercise. In the case of time inadequacy for child, the opposite temporal sequence was also significant: Parents reported shorter sleep hours and lower sleep quality than usual when they had experienced higher time inadequacy for their child during the course of that day. With respect to sleep latency, the temporal pattern also was that time inadequacy predicted sleep: Participants reported longer sleep latencies on nights following days with higher time inadequacy both for their child (at trend level) and for themselves to engage in exercise. In sum, shorter sleep hours and lower sleep quality were more consistent predictors of daily stressors whereas daily stressors more consistently predicted longer sleep latencies. Additionally, our supplementary analyses with calculated sleep duration (i.e., time in bed) revealed an essentially identical pattern (Table 5).

Discussion

Using a daily diary design, this study examined the temporal sequence linking nightly sleep and daily psychological stressors in a sample of employed parents. We expected two different temporal sequences to emerge for different sleep variables. For sleep hours and quality—which reflect replenishment of resources (Sonnentag et al., 2008)—we found that these sleep variables preceded perceptions of stressors in general, with one exception that more time inadequacy for child also preceded shorter sleep hours and poorer quality that night. For sleep latency—which may be influenced by the days' worries and concerns (Akerstedt et al., 2007)—we found that more work-to-family conflict and time inadequacy preceded longer sleep latencies. Our results shed new light on the links between sleep and daily psychosocial stressors. Our findings also underscore the importance of including multiple measures of sleep in studies aimed at illuminating the significance of sleep in health. Confidence in the pattern of result is strengthened by our use of lagged variables within a daily diary design which allowed us to assess sleep-stressor links *on the same day* and *from one day to the next day* after taking into account between-person differences (Bolger et al., 2003, Lee and Almeida, 2016).

Sleep hours and quality precede daily stressors

Experimental studies reveal that sleep loss leads to performance declines and physiological abnormalities (Meier-Ewert et al., 2004, Pejovic et al., 2013, Vgontzas et al., 2004). We know little, however, about the everyday ecology of sleep—that is, how variations in nightly sleep affect daily experiences of stressors within naturalistic settings. Using daily diary data, this study documented that poorer sleep, indexed as shorter sleep hours and lower sleep quality, led to perceptions of more work-to-family conflict and time inadequacy on the next day. These findings are consistent with the idea that sleep can replenish resources and also are important given research that such daily stressors may have implications for long-term health. For example, work-to-family conflict is a risk factor for cardiometabolic disease (Berkman et al., 2015) and time inadequacy is a significant barrier to engaging in health behaviors (American Psychological Association, 2012). Our findings suggest that their links to health may be due, at least in part, to their implications for sleep replenishment. It is noteworthy that average work-to-family conflict was not linked with any of the sleep variables examined in this study, but within-person associations between sleep and work-to-family conflict emerged beyond between-person level associations. For example, people who reported more work-to-family conflict, on average, did not report shorter sleep hours than people who had less work-to-family conflict. However, the effects of work-to-family conflict occurred on occasion by occasion basis, such that individuals reported more work-to-family conflict than usual on days following nights with shorter sleep than usual. Note, however, that we also found that the links between time inadequacy for child and sleep hours and sleep quality were reciprocal. Time inadequacy for child is a salient stressor for parents (Milkie et al., 2004), and our findings suggest that a salient daily stressor can both precede and follow nightly sleep replenishment. For example, on days following nights with poorer sleep, parents may perceive more stressors, including time inadequacy for child; further, on occasions following days when parents feel that they did not have enough time for their child, they may go to bed later or get up earlier to spend more time with their child. These findings highlight the divergent effects of different stressor types on different sleep indicators within the same individual.

Daily stressors precede sleep latency

In the opposite direction, more work-to-family conflict and time inadequacy on a given day preceded longer sleep latency that night. Previous research has documented that psychological stress is directly related to sleep latency but has not established direction of effect (Akerstedt et al., 2007, Drake et al., 2004). By simultaneously testing two temporal sequences in a single model, we found that parents who experienced more stressors on a given day took longer to fall asleep that night—but not the reverse. That is, taking longer to fall asleep was an outcome of daily stressors, rather than a predictor of stressors the next day. Taken together, our study reveals that sleep reflects not only an antecedent of a variety of daily stressors critical to health, but also an outcome of daily stressors.

Limitations

In the face of this study's contributions, some limitations suggest directions for future research. First, the sample was purposively selected from an IT firm, and thus our findings may not generalize to employed parents in other contexts. Moreover, our sample is relatively privileged in education and income compared to other U.S. workers. Future research should examine these processes in other groups of workers, including employed parents with less education and income. Related to the measurement of time adequacy, we were only able to include perceptions of time adequacy for children and exercise, but other perceptions of time inadequacy should be examined in future studies, given prior work indicating negative between-person relations between sleep quantity and other activities like socializing and grooming (Basner et al., 2014). Furthermore, this study used self-reports to measure daily work-to-family conflict, time inadequacy, and nightly sleep, which poses a potential risk for a common-method bias (Podsakoff et al., 2003). Although we focused on within-person variations after controlling for between-person associations, future research may benefit from incorporating more objective markers of sleep, such as actigraphy.

Clinical Implications

Our findings underscore the importance of understanding daily stressors in treatments for patients with sleep disorders. For example, daily worries about work and family and interpersonal conflicts may exacerbate sleep difficulties for individuals with insomnia. The negative effects of these types of daily stressors may accumulate over time to contribute to the development of insomnia. Indeed, a key message to communicate to patients in cognitive therapy may be, "Do not blame insomnia for all daytime impairments because there may be other explanations (worries about family, conflicts with coworkers) for these deficits," (Morin et al., 2017). Extending this approach using the current findings, CBT-I (Cognitive Behavioral Therapy for Insomnia) could include a direct and systematic evaluation of daily work-to-family conflict and time inadequacy for child and self to identify potentially modifiable perceptions and experiences that affect insomnia.

Conclusions

We found that shorter sleep hours and lower sleep quality (but not shorter sleep latency) tended to lead to more stressors on the following day. In contrast, daily stressors preceded longer sleep latencies that night, but did not precede nights with short sleep duration or poor sleep quality. One exception to this consistent pattern was that more time inadequacy for child also preceded shorter sleep hours and poorer quality that night. Strengths of this study include a daily diary design, which sampled multiple assessments with ecological validity, and an analytic approach that simultaneously tested two directions of effects. At the most general level, our findings suggest that nightly sleep should be considered at the core of a daily health-stress model. By identifying daily antecedents and consequences of sleep, we will be able to better target interventions to improve individual health.

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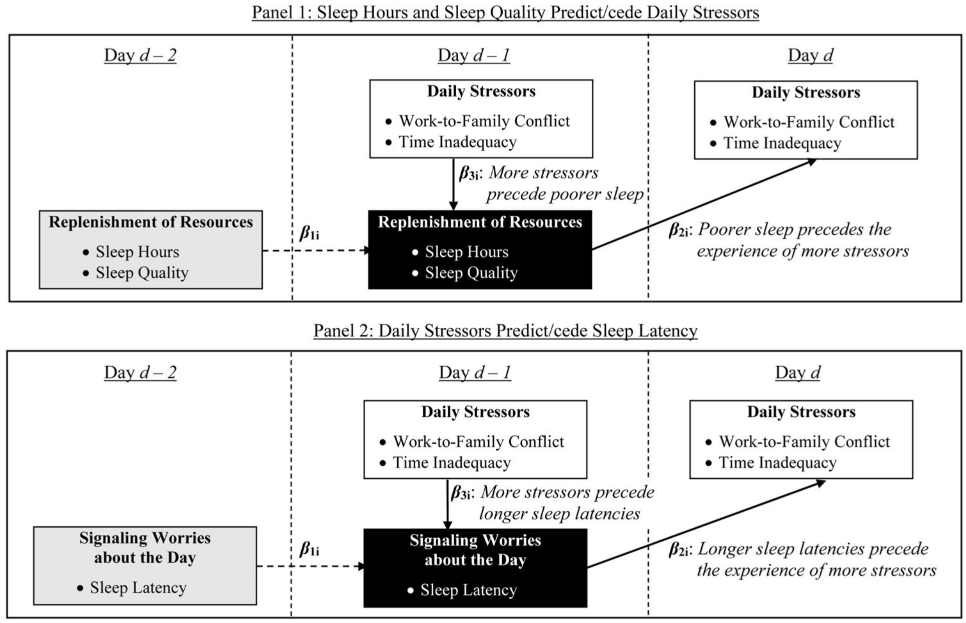

Figure 1. Temporal directions linking nightly sleep and daily psychosocial stressors

Note. Black boxes represent outcome variables, white boxes represent the predictors, and gray boxes and dotted arrows represent controls (other covariates not included). Solid arrows and betas indicate each temporal direction tested (see also data analysis).

Table 1

Baseline descriptive statistics and correlations of all variables

	M (*SD*)	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Age	45.19 (5.87)	−0.07	**−0.27**	0.04	0.04	**−0.23**	**0.35**	0.19	0.06	0.09	0.16	**0.27**	0.08	0.02	−0.02	−0.06	−0.16	−0.18	−0.06	0.10
2. Women (vs. Men)	0.46 (0.50)		**−0.21**	−0.16	−0.11	**−0.21**	0.19	−0.01	0.15	−0.09	−0.09	−0.16	0.16	0.09	0.04	0.11	0.13	0.15	0.10	−0.04
3. Married (vs. Unmarried)	0.88 (0.32)			0.02	0.12	0.06	**−0.23**	0.09	−0.08	0.03	0.14	−0.11	−0.05	−0.11	**−0.26**	−0.12	0.18	0.15	−0.01	**−0.21**
4. White (vs. Non-White)	0.70 (0.46)				0.14	0.13	0.08	−0.10	−0.02	−0.03	−0.04	0.19	0.02	0.14	**0.21**	0.14	−0.01	−0.07	0.05	−0.05
5. College graduates (vs. Not)	0.79 (0.41)					0.08	−0.12	−0.08	−0.10	−0.11	−0.04	0.10	−0.02	0.19	0.15	0.01	0.07	0.06	0.05	0.07
6. Number of children	2.09 (1.12)						**−0.25**	−0.09	0.00	0.02	−0.10	0.08	−0.17	0.04	**0.22**	0.14	−0.17	−0.09	−0.16	0.07
7. Child’s age	13.32 (2.26)							0.10	−0.02	0.06	0.00	0.05	−0.09	−0.12	0.05	−0.05	0.08	0.03	0.05	0.08
8. Child’s gender, Girl (vs. Boy)	0.54 (0.50)								0.04	0.18	−0.05	−0.01	−0.04	**−0.27**	**−0.27**	**−0.21**	0.08	−0.05	0.11	−0.05
9. Merger, Pre-informed (vs. Not)	0.47 (0.50)									0.04	−0.12	**−0.26**	−0.03	0.07	−0.13	−0.10	−0.03	0.11	−0.05	0.16
10. Schedule control	3.58 (0.74)										−0.08	−0.12	**−0.20**	**−0.36**	**−0.28**	**−0.20**	0.06	0.01	0.05	−0.04
11. Work hours	511.80 (71.92)											0.00	0.09	**0.28**	0.10	0.09	−0.16	**−0.20**	−0.10	−0.03
12. Proportion of workdays	0.75 (0.09)												−0.02	**0.31**	**0.30**	**0.28**	−0.05	−0.15	−0.05	−0.01
13. Intervention (vs. Control)	0.60 (0.49)													0.11	−0.03	0.10	0.07	0.03	0.07	−0.17
14. Work-to-Family Conflict	1.58 (0.53)													*0.56*	**0.46**	**0.47**	−0.14	−0.05	−0.15	0.10
15. Time inadequacy for Child	2.51 (0.60)													**0.43**	*0.26*	**0.54**	−0.16	−0.17	**−0.23**	0.12
16. Time inadequacy for Self	2.77 (0.66)													**0.35**	**0.40**	*0.40*	−0.13	−0.12	**−0.35**	0.10
17. Sleep hours	6.82 (0.71)													**−0.16**	**−0.20**	**−0.18**	*0.31*	**0.78**	**0.35**	**−0.27**
18. Sleep duration (in minutes)	442.52 (40.99)													**−0.14**	**−0.23**	**−0.18**	**0.81**	*0.30*	0.08	0.16
19. Sleep quality	3.09 (0.35)													**−0.14**	**−0.11**	**−0.19**	**0.44**	**0.22**	*0.24*	**−0.32**
20. Sleep latency	19.18 (11.93)													0.07	0.01	0.04	**−0.19**	**0.11**	**−0.25**	*0.29*
21. Day of week (Sun=0 ~ Sat=6)	3.01 (1.95)													0.01	**0.07**	0.04	0.02	−0.03	**0.09**	0.01

Note. N = 120 parents, 816 days at baseline. Unadjusted Means and Standard Deviations were based on person-means across days at baseline (except for day of week variable); Intra-Class Correlations (ICC=between-person level variance/total variance) are reported on the diagonal in *italics*. Numbers below the diagonal are within-person level correlations and those above the diagonal are between-person level correlations; Correlations in bold were significant at $p < .05$.

Table 2

Results from multilevel models examining the effects of covariates on nightly sleep

	Sleep hours	Sleep quality (1=*very badly* to 4=*very well*)	Sleep latency (in minutes)
	***B* (*SE*)**	***B* (*SE*)**	***B* (*SE*)**
Model 1: Covariates			
Fixed effects			
Intercept, adjusted mean	6.35 (0.31) ***	2.89 (0.17) ***	29.26 (5.30) ***
Age	−0.02 (0.01)	−0.01 (0.01)	0.00 (0.26)
Women (vs. Men)	0.14 (0.16)	0.03 (0.08)	−3.48 (2.63)
Married (vs. Unmarried)	0.49 (0.23) *	0.00 (0.12)	−10.11 (3.89) **
White (vs. Non-White)	−0.01 (0.16)	0.05 (0.08)	−2.40 (2.70)
College graduates (vs. Not)	0.13 (0.18)	0.05 (0.10)	4.47 (3.00)
Number of children	−0.10 (0.06)	−0.05 (0.03)	0.20 (1.07)
Target child’s age	0.04 (0.04)	0.01 (0.02)	0.37 (0.59)
Target child’s gender, Girl (vs. Boy)	0.03 (0.15)	0.09 (0.08)	−1.21 (2.51)
Merger, Pre-informed (vs. Not)	−0.02 (0.15)	−0.04 (0.08)	2.89 (2.52)
Schedule control	0.05 (0.10)	0.03 (0.05)	−0.99 (1.68)
Work hours	−0.00 (0.00)	−0.00 (0.00)	0.00 (0.02)
Proportion of workdays	0.60 (0.86)	−0.01 (0.45)	−4.82 (14.40)
Wave, 12 months (vs. Baseline)	0.20 (0.12)	0.02 (0.06)	1.28 (2.02)
Intervention effect at 12 months	0.05 (0.14)	0.06 (0.08)	−1.52 (2.47)
Day of week (Sun=0 ~ Sat=6)	−0.01 (0.02)	0.02 (0.01) **	−0.17 (0.24)
Previous nights’ sleep	−0.16 (0.03) ***	−0.10 (0.03) ***	−0.15 (0.03) ***
Random effects			
Person level variance	0.33 (0.08) ***	0.10 (0.02) ***	88.70 (22.63) ***
Burst-level variance	0 (0.00)	0.03 (0.01) *	33.34 (15.52) *
Auto-correlation[1]	0.29 (0.05) ***	0.16 (0.07) *	0.23 (0.07) **
Residual variance	1.30 (0.07) ***	0.34 (0.02) ***	295.00 (19.17) ***

Note. 1632 daily observations were clustered within 102 employees who provided daily diaries both at baseline and 12-month follow-up; 1380–1384 observations were used in the analyses because of missing values.

[1] AR(1) function was used to specify a first-order autoregressive variance structure, such that consecutive sleep observations (within each burst) are more highly correlated than non-consecutive observations.

† $p < .10$,

* $p < .05$,

** $p < .01$,

*** $p < .001$

Table 3

Results from multilevel models examining the temporal direction between daily work-to-family conflict and nightly sleep

	Sleep hours	Sleep quality (1=*very badly* to 4=*very well*)	Sleep latency (in minutes)
	B **(*SE*)**	***B*** **(*SE*)**	***B*** **(*SE*)**
Model 2: Covariates and Work-To-Family Conflict (WTFC)			
Fixed effects			
Intercept, adjusted mean	5.95 (0.33)***	2.85 (0.18)***	33.17 (5.78)***
Previous nights' sleep Within-person lagged effect	−0.05 (0.04)	−0.05 (0.03)	−0.03 (0.04)
Average WTFC Between-person effect	−0.13 (0.18)	−0.13 (0.10)	2.68 (3.10)
Sleep *precedes* WTFC Within-person effect	−0.21 (0.06)***	−0.11 (0.04)**	−0.33 (1.01)
WTFC *precedes* sleep Within-person lagged effect	−0.07 (0.06)	−0.03 (0.04)	2.42 (1.02)*
Random effects			
Person level variance	0.36 (0.08)***	0.11 (0.03)***	113.18 (25.55)**
Burst-level variance	0.09 (0.06)†	0.02 (0.02)	38.56 (16.07)**
Auto-correlation[1]	0.11 (0.08)	0.05 (0.08)	0.08 (0.08)
Residual variance	0.79 (0.06)***	0.28 (0.02)***	183.95 (13.44)***

Note. 1632 daily observations were clustered within 102 employees who provided daily diaries both at baseline and 12-month follow-up; 834–791 observations were used in the analyses because only workdays were included and also because the lagged design excluded the first day's reports at each wave; Covariates from Model 1 (in Table 1) were retained in Model 2.

[1] AR(1) function was used to specify a first-order autoregressive variance structure, such that consecutive sleep observations (within each wave) are more highly correlated than non-consecutive observations.

† $p < .10$,

* $p < .05$,

** $p < .01$,

*** $p < .001$

Table 4

Results from multilevel models examining the temporal direction between daily time inadequacy and nightly sleep

	Sleep hours	Sleep quality (1=*very badly* to 4=*very well*)	Sleep latency (in minutes)
	***B* (*SE*)**	***B* (*SE*)**	***B* (*SE*)**
Model 3: Covariates and Time Inadequacy for Child (TIC)			
Fixed effects			
Intercept, adjusted mean	6.30 (0.32)***	2.91 (0.16)***	29.48 (5.40)***
Previous nights' sleep Within-person lagged effect	−0.15 (0.03)***	−0.09 (0.03)**	−0.17 (0.03)***
Average TIC Between-person effect	−0.13 (0.14)	−0.16 (0.07)*	0.78 (2.48)
Sleep *precedes* TIC Within-person effect	−0.16 (0.03)***	−0.04 (0.02)*	−0.05 (0.52)
TIC *precedes* sleep Within-person lagged effect	−0.08 (0.03)*	−0.04 (0.02)*	1.01 (0.53)†
Random effects			
Person level variance	0.34 (0.08)***	0.08 (0.02)***	89.29 (23.02)***
Burst-level variance	0.02 (0.05)	0.03 (0.01)*	29.34 (16.25)*
Auto-correlation[1]	0.27(0.06)***	0.12 (0.07)†	0.25 (0.07)***
Residual variance	1.25 (0.08)***	0.33 (0.02)***	299.18 (19.96)***
Model 4: Covariates and Time Inadequacy for Self (TIS; to exercise)			
Fixed effects			
Intercept, adjusted mean	6.34 (0.31)***	2.89 (0.16)***	28.98 (5.23)***
Previous nights' sleep Within-person lagged effect	−0.16 (0.03)***	−0.09 (0.03)***	−0.17 (0.03)***
Average TIS Between-person effect	−0.11 (0.12)	−0.20 (0.06)***	1.44 (2.02)
Sleep *precedes* TIS Within-person effect	−0.18 (0.03)***	−0.07 (0.02)***	−0.09 (0.56)
TIS *precedes* sleep Within-person lagged effect	−0.03 (0.03)	−0.02 (0.02)	1.39 (0.55)*
Random effects			
Person level variance	0.32 (0.08)***	0.08 (0.02)***	86.65 (22.31)***
Burst-level variance	0.02 (0.06)	0.03 (0.01)*	20.60 (16.39)
Auto-correlation[1]	0.28 (0.06)***	0.13 (0.07)†	0.27 (0.07)***
Residual variance	1.25 (0.08)***	0.32 (0.02)***	298.52 (21.02)***

Note. 1632 daily observations were clustered within 102 employees who provided daily diaries both at baseline and 12-month follow-up; 1380–1291 observations were used in the analyses because of missing values in variables and also because the lagged design excluded the first day's reports at each wave; Covariates from Model 1 (in Table 1) were retained in Models 3 and 4.

[1] AR(1) function was used to specify a first-order autoregressive variance structure, such that consecutive sleep observations (within each wave) are more highly correlated than non-consecutive observations.

† $p < .10$,

*$p < .05$,

**$p < .01$,

***$p < .001$

Table 5

Results from multilevel models examining the temporal direction between daily work-to-family conflict, time inadequacy, and nightly sleep duration (i.e., time in bed)

Fixed effects	***B* (*SE*)**	***B* (*SE*)**	***B* (*SE*)**
Model 2: Covariates and Work-To-Family Conflict (WTFC)			
Intercept, adjusted mean	406.17 (19.92) ***		
Previous nights' sleep Within-person lagged effect	0.02 (0.04)		
Average WTFC Between-person effect	5.33 (10.73)		
Sleep *precedes* WTFC Within-person effect	−10.08 (3.67) **		
WTFC *precedes* sleep Within-person lagged effect	−3.54 (3.72)		
Model 3: Covariates and Time Inadequacy for Child (TIC)			
Intercept, adjusted mean		425.13 (18.38) ***	
Previous nights' sleep Within-person lagged effect		−0.07 (0.03) *	
Average TIC Between-person effect		−9.21 (8.36)	
Sleep *precedes* TIC Within-person effect		−10.79 (1.83) ***	
TIC *precedes* sleep Within-person lagged effect		−3.64 (1.88)†	
Model 4: Covariates and Time Inadequacy for Self (TIS; to exercise)			
Intercept, adjusted mean			428.25 (18.38) ***
Previous nights' sleep Within-person lagged effect			−0.08 (0.03) **
Average TIS Between-person effect			−4.79 (7.00)
Sleep *precedes* TIS Within-person effect			−11.15 (1.99) ***
TIS *precedes* sleep Within-person lagged effect			0.11 (1.98)
Random effects			
Person level variance	1463.65 (300.53) ***	1268.75 (264.28) ***	1265.71 (263.65) ***
Burst-level variance	148.61 (161.55)	4.45 (142.97)	0.00 (0.00)
Auto-correlation [1]	0.06 (0.07)	0.20 (0.06) **	0.22 (0.06) ***
Residual variance	2808.04 (185.40) ***	4018.18 (226.31) ***	4088.64 (208.59) ***

Note. 1632 daily observations were clustered within 102 employees who provided daily diaries both at baseline and 12-month follow-up; 834–791 observations were used in Model 1 because only workdays were included and 1380–1291 observations were used in Model 3 & 4 because the lagged design excluded the first day's reports at each wave; Covariates from Model 1 (in Table 1) were retained.

[1] AR(1) function was used to specify a first-order autoregressive variance structure, such that consecutive sleep observations (within each wave) are more highly correlated than non-consecutive observations.

† $p < .10$,

* $p < .05$,

** $p < .01$,

*** $p < .001$